Research Article

Predictors of readmission to acute care during inpatient rehabilitation for non-traumatic spinal cord injury

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Objectives: To investigate the frequency of and reasons for readmissions to acute care (RTAC) during inpatient rehabilitation (IPR) after non-traumatic spinal cord injury (NT-SCI). To develop a predictive model for RTAC using identified risk factors.
Design: Retrospective case-control.
Setting: Academic IPR hospital.
Participants: Individuals with NT-SCI admitted to an academic SCI rehabilitation unit from January 2014-December 2015.
Interventions: Not applicable.
Main Outcome Measures: Readmissions to acute care services from IPR.
Results: Thirty-seven participants (20%) experienced a RTAC for a total of 39 episodes. Thirty-five experienced 1 RTAC, while two had 2. The most common medical reasons for RTAC were infection (27%), neurological (27%), and noninfectious respiratory (16%). Multivariable logistic regression was used to develop a model to predict RTAC. Paraplegia was associated with 3.2 times increase in the odds of RTAC ($P = 0.03$). For every unit increase in FIM-Motor, there was a 5% reduction in the odds of RTAC ($P = 0.03$) Body mass index less than 30 decreased odds of RTAC by 61% ($P = 0.004$).
Conclusion: RTACs were associated with body mass index greater than 30, decreased FIM-Motor subscore on admission, and paraplegia. Physiatrists caring for the non-traumatic SCI patient need be more circumspect of individuals with these parameters to potentially prevent the problems necessitating acute care transfer.

Keywords: Spinal cord injuries, Quality measures, Outcome assessment, Rehabilitation, Patient readmission

List of Abbreviations

FIM	Function independence measure
IPR	Inpatient rehabilitation
NT-SCI	Non-traumatic spinal cord injury
IQR	Interquartile range

Introduction

Non-traumatic spinal cord injury (NT-SCI) which is caused by etiologies such as spinal stenosis, malignant compression, vascular ischemia, and congenital disease makes up a significant portion of inpatient rehabilitation (IPR) SCI admissions.[1,2] A study by McKinley *et al.* at Virginia Commonwealth University looked at SCI patients admitted to their IPR unit and found that NT-SCI accounted for 39% of SCI admissions.[3] NT-SCI tends to occur at older ages and is therefore expected to increase in incidence as the United States population ages.[4] The decreased functional abilities secondary to these injuries can significantly impair the patient's quality of life.[5]

IPR for NT-SCI patients has been demonstrated to improve functional outcomes for activities of daily living, transfers and locomotion, and neurologic recovery.[6–8] Kennedy and Chessel demonstrated rehabilitation gains for NT-SCI are comparable to those for traumatic SCI.[9] Effective completion of the rehabilitation program is essential for maximum rehabilitation gains and community reintegration. In the United States acute care lengths of stay have declined from 24 days in the 1970s to 11 days in 2016, while SCI IPR lengths of stay have also decreased from 98 days in the 1970s to 35 days in 2016.[10] The shortening of both

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acute care and rehabilitation lengths of stay places greater pressure on acute inpatient rehabilitation providers to manage all aspects of medical care and rehabilitation in a compressed time frame.[11]

Readmissions to acute care (RTAC) typically occur secondary to unexpected medical complications. These readmissions come with significant financial implications, emotional distress for both patients and their families, and interrupt a patients' rehabilitation progress. Of note, the Centers for Medicare and Medicaid Services have established a goal to reduce inappropriate 30-day all-cause readmission rates while improving quality of care and safety.[12] Predictors of RTAC have been studied for traumatic brain injury, traumatic SCI, burn, stroke, and multiple malignancies.[11,13–21] Re-hospitalizations among those with chronic SCI have been studied as well, focusing on those who have already completed IPR.[22]

There is a paucity of literature addressing the risk factors and reasons for RTAC in the NT-SCI population undergoing IPR. Identification of these risk factors will help determine those at most risk for RTAC events and guide the development of potential preventative and interventional strategies to avert RTACs. The primary aims of this study are to (1) investigate the frequency of and reasons for RTAC during inpatient rehabilitation after NT-SCI, (2) identify risk factors associated with RTAC, and to (3) develop a predictive model for identifying at risk patients.

Methods

Participants

This retrospective study evaluated patients with NT-SCI admitted to an academic SCI rehabilitation unit from January 2014-December 2015 who experienced an RTAC. All unplanned interruptions of IPR requiring admission to an acute care hospital were considered to represent an RTAC. Reasons for RTAC were grouped into the following categories: surgery, neurologic (e.g., mental status change, new onset weakness, stroke), cardiac (e.g., acute coronary syndrome, chest pain secondary to intrathoracic hematoma), non-infectious respiratory (e.g., pulmonary embolism, respiratory distress secondary to worsening lung metastasis), infection (e.g., urinary tract infection, wound infection, pneumonia), renal, and gastrointestinal.

Inclusion criteria were: (1) admitting diagnosis of new onset NT-SCI and (2) patient's initial admission to IPR. Exclusion criteria were: (1) concurrent TBI, (2) age less than 18, and (3) RTAC was planned. Two hundred and thirteen patients in total were consecutively admitted with NT-SCI during the study period. Twenty-six patients were excluded for having elective surgery, a chronic SCI and/or previous IPR admission prior to the study period, resulting in a study group of 187 patients.

Thirty-seven patients were identified as having experienced an RTAC. These patients were compared to 150 NT-SCI patients admitted during that same period who did not require acute care transfer. In those with repeat IPR admissions during the study interval, only the initial admission was studied.

Procedure

Approval was obtained from our institutional review board. The 0500 case mix groups (spinal cord dysfunction, non-traumatic) were used to obtain patient records of NT-SCI admissions during the study period.[23] Data was collected from patient charts and organized into 6 categories: demographic information, hospital admission characteristics, RTAC characteristics, clinical characteristics, functional status, and SCI specific.

1. Demographic information: age, sex, race, payer source, marital status, smoking history, alcohol abuse history, and intravenous drug use history.
2. Hospital admission characteristics: diagnosis, date, day of week, acute care admission date, length of stay in acute care, and admitting hospital.
3. RTAC characteristics: date, length of IPR stay prior to RTAC, total IPR length of stay, and reason for transfer (as documented in rehabilitation discharge summary).
4. Clinical characteristics: body mass index, psychiatric diagnosis, hypertension, hyperlipidemia, new deep vein thrombosis diagnosed in acute care prior to IPR admission, and their Charlson Comorbidity Index.[24]
5. Functional status: Functional Independence Measure (FIM) motor and cognitive subscales at IPR admission.[25]
6. SCI specific: tetraplegia (C1-C8), paraplegia (T1 and below), American Spinal Injury Association (ASIA) Impairment Scale (AIS) grade, level of injury, and their NT-SCI etiology as documented on IPR admission history and physical categorized into degenerative disease of spine, malignancy, infectious, and other.

Statistical methods

All analyses were performed using Stata 14.2 (StatraCorp, College Station, TX, USA). Descriptive statistics were used to evaluate variable frequencies between the two groups. Nonparametric statistics were used to calculate differences among categories and their relationship to the dependent variable of RTAC. Percentages or medians and interquartile ranges are reported. Multivariable logistic regression was performed using the variables that were significant in univariate analyses to develop a model for predicting RTAC. Values of $P < 0.05$ were considered statistically significant. Odds ratios, sensitivity and specificity of the model, and 95% confidence intervals were calculated.

Results

Among the sample of 187 patients, 37 (20%) experienced an RTAC for a total of 39 episodes. Thirty-five experienced 1 RTAC, while two had 2. Demographic and injury characteristics of those who did and did not have an RTAC are summarized in Table 1. The sample was 63% male, 60% African-American, 41% married, and 56% non-obese (body mass index < 30). The most common pre-existing medical conditions of the cohort were hypertension (67%), a positive smoking history (40%), hyperlipidemia (37%), and diabetes mellitus (30%). The distribution of documented AIS grades included 7 patients with AIS A (4%), 6 AIS B (3%), 53 AIS C (28%), and 119 AIS D (64%). Two patients did not have documented AIS grades.

The most common causes of injury in the RTAC group were malignancy (43%) and degenerative disease of the spine (27%). Medical reasons accounted for 84% of RTACs, compared to 16% for surgery. The most common medical reasons for RTAC were infection (26%), neurological (26%), and noninfectious respiratory (15%). Surgical RTACs occurred for fractures sustained during IPR and wound complications. Reasons for RTAC occurrences are listed in Table 2.

Median days from rehabilitation admission to first RTAC was 7 (IQR, 4.5-13.5). The majority (73%) had RTAC that occurred within 10 days of admission. The median length of stay in acute care prior to initial IPR admission was the same for the RTAC and non-RTAC groups (11 days (IQR, 7-19.5) and 11 days (IQR, 7-16); P = 0.54).

The total median IPR length of stay was the same for the RTAC and non-RTAC groups (17 days (IQR 7-16) and 17 days (IQR, 12-25); P = 0.32). Twenty-one patients with an RTAC did not return to IPR. The majority of patients with a RTAC episode were admitted to IPR on Wednesday (27%) and Friday (27%), followed by Tuesday (19%). RTACs occurred most frequently on Friday (27%), followed by Monday (24%) and Tuesday (24%).

Table 3 displays the results of the univariate analysis on selected clinical characteristics. Through the univariate analyses we were able to identify 6 variables with statistically significant associations to RTAC. These were new onset deep vein thrombosis in acute care prior to IPR admission, NT-SCI etiology, paraplegia, FIM-Motor subscore at admission, body mass index greater than 30, and their Charlson Comorbidity Index.

Table 1 Patient demographics and injury characteristics.

Category	RTAC (n = 37)	No RTAC (n = 150)	P Value
Age at injury (y)	61 (51.5-68.5)	59.5 (51-67)	0.6
Sex, male	57	64	0.41
Race			0.13
White	49	32	
Black	46	64	
Other	5	4	
Payer			0.29
Medicare	51	37	
Medicaid	8	9	
Private/Other	41	54	
Marital status, % married	49	39	0.27
Etiology of injury			**0.008**
Degenerative disease of spine	27	50	
Malignancy	43	25	
Infectious	3	11	
Other	27	14	
ASIA group			0.17
C1-4 AIS grades A-C	14	11	
C5-8 AIS grades A-C	6	5	
Paraplegia AIS grades A-C	31	17	
AIS all grades D	49	67	
Paraplegia	73	47	**0.005**

ASIA, American Spinal Injury Association; AIS, ASIA Impairment Scale.
NOTE: Age is median (IQR), all other values are percentages.

Table 2 Primary reasons for RTAC (n = 37).

RTAC Reason	Frequency n (%)
Infection	10 (27)
Neurologic	10 (27)
Surgery/procedure	6 (16)
Noninfectious respiratory	6 (16)
Cardiac	3 (8)
Gastrointestinal	1 (3)
Other (IVIG)	1 (3)

IVIG, intravenous immunoglobulin.

Table 3 Univariate analysis of selected clinical characteristics influencing return to acute care.

Category	RTAC (n = 37)	No RTAC (n = 150)	P Value
Acute care length of stay (d)	11 (7-19.5)	11 (7-16)	0.54
Total IPR length of stay (d)	17 (8.5-25)	17 (12-25)	0.32
FIM-Motor at admission	28 (20.5-42.5)	37 (27-48.3)	**0.006**
FIM-Cognitive at admission	28 (24-30)	30 (25-31)	0.08
Hypertension	62	69	0.57
Hyperlipidemia	43	35	0.8
Smoking history	30	43	0.15
Intravenous drug history	14	13	0.98
Psychiatric diagnosis	22	13	0.17
Deep vein thrombosis in acute care	30	14	**0.02**
Body mass index > 30	59	40	**0.04**
Charlson Comorbidity Index	6 (2.5-7.5)	3.5 (2-7)	**0.04**

RTAC, readmission to acute care; IPR, inpatient rehabilitation; FIM, functional independence measure.
NOTE: Acute care length of stay, total IPR length of stay, FIM-Motor at admission, FIM-Cognitive at admission, and Charlson Comorbidity Index are median (IQR), all other values are percentages.

Table 4 Multivariable logistic regression model of RTAC predictors (n = 187).

Variable	Odds ratio	SE	P value	95% CI
Body mass index < 30	0.39	0.17	0.03	0.16-0.9
FIM-Motor at admission	0.95	0.017	0.004	0.92-0.98
Paraplegia	3.2	1.7	0.03	1.1-9.2

CI, confidence interval; FIM, functional independence measure.

All six variables were simultaneously entered into a multivariable logistic regression model. The omnibus of the overall model was statistically significant (χ^2 (8) = 36.01, P < 0.00001). The McFadden's pseudo-R^2 of the model was 0.19. Of the six variables, FIM-Motor, body mass index, and paraplegia were significant predictors of RTAC. For every unit increase in FIM-Motor, there was a 5% reduction in the odds of RTAC (P = 0.004). For body mass index < 30, there was a 61% reduction in the odds of RTAC (P = 0.03). The increase in the odds of RTAC was 3.2 greater for paraplegia (P = 0.03) compared to tetraplegia. The odds ratios and 95% confidence intervals of these results are depicted in Table 4.

This model showed acceptable discrimination (area under curve = 0.79 and Brier score = 0.13). Model calibration was good (Hosmer-Lemeshow test: P = 0.25). Using the default cutoff risk probability of 0.50 resulted in a sensitivity (of RTAC) of 24% but a specificity of 95%. Positive predictive value was 56% while negative predictive value was 84%. There was no indication of substantial collinearity: all variation inflation factors were less than 1.35.

Discussion

The primary aim of this study is to identify risk factors associated with RTAC among rehabilitation patients with NT-SCI. Factors related to increasing medical complexity and pressures for discharging patients undoubtedly affect RTAC rates. To our knowledge, this study is the first to look specifically at the common reasons for and risk factors of RTAC in the NT-SCI population undergoing IPR. We found that 20% of NT-SCI patients undergoing IPR were transferred back to acute care for unexpected medical complications or surgeries. RTACs for medical reasons occurred most frequently for infection, neurologic, and non-infectious respiratory issues. Risk factors significant in predicting RTAC were FIM-Motor subscore at admission, body mass index greater than 30, and paraplegia. The etiologies and levels of injury reported here are similar to those found in previous studies on NT-SCI patients undergoing IPR.[1,3]

Our overall rate of RTAC was higher than the 11% rate reported by New *et al.* for NT-SCI.[26] Albeit our sample had a larger proportion of tumor etiology by 12%, a population that they showed to have a higher frequency of RTAC. Paraplegia being a significant predictor of RTAC was an unexpected result given the increased level of care typically required for tetraplegics. A potential explanation for this result is the differences in etiologies amongst the two groups; malignancy was much more prevalent in the RTAC group compared to degenerative disease in the non-RTAC group. Malignant etiologies of NT-SCI usually result in paraplegia, and degenerative disease is the most common etiology of tetraplegia for NT-SCI.[27,28] In our study, 89% of those with malignant etiologies were paraplegic, a finding consistent with the tumor localization numbers found by Prasad and Schiff.[27] Malignancy, especially metastatic, drastically elevates a patient's Charlson Comorbidity Index, a factor found to be significant in our univariate but not multivariable analysis. One would expect the presence of increased comorbidities to influence complications. Perhaps this is partially reflected in paraplegia's significance and the typical NT-SCI paraplegic patient is more medically complex and thus more prone to the complications necessitating RTACs.

Lower FIM-Motor subscores impacting RTACs is not particularly surprising. Hammond *et al.* demonstrated lower FIM-Motor at admission and higher body mass index to be associated with medical RTAC among traumatic SCI patients.[11] Decreased functional status proving predictive of re-hospitalization is corroborated by Mahmoudi *et al.* who found a 10 point increase in total FIM score at IPR admission resulted in lower re-hospitalization rates for SCI patients.[29] Implementation of efforts to improve patient's functional status prior to IPR admission could prove beneficial in prevention of RTACs. Previous studies have shown early rehabilitation in the acute care setting to be clinically feasible and improve outcomes.[30–32]

Infection and non-infectious respiratory were two of the most common reasons for RTAC in our study. This is consistent with the findings of Hammond *et al.* on RTAC causes in the traumatic SCI population and Cardenas *et al.* on SCI re-hospitalizations after completion of IPR, who found infection and non-infectious respiratory causes to account for most medical RTACs.[11,33] The finding of obesity's significant association to RTAC makes intuitive sense. These patients have an increased prevalence of additional medical

comorbidities.[34] Obesity has been shown to be associated with the development of medical complications such as pneumonia, pulmonary embolism, and urinary tract infection in those with SCI.[35] As previously mentioned obesity increased RTAC risk in traumatic SCI. While not immediately modifiable, awareness of the increased incidence of complications in obese patients is warranted.

Surgical RTACs occurred for fractures sustained during IPR and wound complications. Increased deterioration of skeletal architecture is a known consequence of SCI, leading to an increased risk of fracture.[36] Any patient who undergoes surgery is at risk for complications such as dehiscence, wound infection, or seroma. Many of the NT-SCI patients are being admitted acutely after spinal surgery and thus heightened awareness of these potential complications is important.

These results are useful for several reasons. RTACS are costly and can negatively impact the functional gains attainable from IPR. Only 43% of patients with an RTAC returned to IPR and thus the majority did not receive the maximum benefit obtained from successful completion of a comprehensive rehabilitation program. Our findings may guide future quality improvement studies in developing preventative strategies and surveillance policies in order to reduce RTACs. Future studies are needed to analyze if these RTACs are preventable. One strength of this study is that to our knowledge it is the first to specifically analyze the demographic and clinical characteristics predicting RTAC in the NT-SCI population. Our use of a validated comorbidity index, functional measures, and other clinical characteristics encompass a broad range of the possible factors present in patients who experience these complications.

Study limitations

This study's limitations include its retrospective nature and fairly small sample size. Difficulty in controlling for bias is an inherent limitation of retrospective studies. Generalizability of these results may be limited secondary to only one academic teaching hospital being studied. Different physiatrists will have their own thresholds for transferring a patient to acute care secondary to medical instability. Local resources for pathology and radiology, nursing expertise, and after-hours medical staffing vary amongst institutions and could prove influential in decisions to transfer to acute care. These factors cannot be controlled in a retrospective study. Alcohol abuse was not analyzed secondary to lack of homogeneity in its documentation and may be beneficial to evaluate in future studies. Presence of comorbid musculoskeletal conditions is common in NT-SCI patients and they were not assessed in this study. These factors need to be taken into account when analyzing the results of this study. Future studies could pool patient data from several health care systems when evaluating risk factors for RTAC in the NT-SCI population. Overall, this clinical prediction model provides a good starting point, but additional predictors are needed (pseudo-$R^2 = 0.19$), along with a larger sample size.

Conclusion

RTACs were associated with decreased FIM-Motor subscore on admission, body mass index greater than 30, and paraplegia. 20% of NT-SCI patients undergoing IPR were transferred back to acute care for unexpected medical complications or surgeries. RTACs for medical reasons occurred most frequently for infection, neurologic, and non-infectious respiratory issues. Physiatrists caring for the NT-SCI patient need be more aware of individuals with these parameters to potentially prevent the problems necessitating acute care transfer.

Disclaimer statements

Contributors None.

Conflict of interest The authors have no conflicts of interest to report.

Ethics approval None.

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